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Impact of Climatic and Seasonal Variations on Iodine Deficiency Disorders: A Case Study of Selected Villages in Agastyamuni Block, Rudraprayag District, Garhwal Himalaya"

Dr. Naveen Chandra Khanduri

Govt. P.G. College Agastyamuni, Rudraprayag

Uttarakhand, India, 246421

Abstract:
Iodine deficiency, a natural ecological phenomenon, is primarily driven by historical glaciations and intensified by environmental factors such as leaching due to precipitation, leading to Environmental Iodine Deficiency (EID) in various regions, including the mountainous areas of the Indian Subcontinent, China, Europe, and parts of Africa. This deficiency impacts soil quality and, consequently, the iodine content of plant life, particularly affecting populations reliant on subsistence agriculture. Notably, the Himalayan goitre belt, encompassing the Garhwal Himalaya, is traditionally viewed as an iodine-deficient area. However, our investigation revealed a surprisingly low incidence of goitre, with only 2.3% of the population exhibiting palpable, non-visible goitre and no visible cases. Urinary iodine excretion studies corroborated mild iodine deficiency among residents, suggesting a paradox where low iodine prophylaxis correlates with minimal iodine deficiency disorders (IDDs). This study conducts a comprehensive survey assessing iodine consumption, salt procurement and usage patterns, dietary habits, and socio-economic status across 06 villages in Rudraprayag district. Findings indicate a prevalent reliance on un-iodized salt, raising questions about the mechanisms sustaining low IDD incidence in this iodine-deficient region. The study also includes pedigree analyses to explore familial patterns of IDDs linked to goitre, contributing to a deeper understanding of iodine dynamics in this unique ecological context.

Keywords: IDD - Iodine Deficiency Disorders

EID - Environmental Iodine Deficiency

UIC - Urinary Iodine Concentration

Introduction

This study investigates dietary salt usage patterns and iodine content among 181 families across 06 villages in Rudraprayag District. Using a structured questionnaire, data were collected on salt type, purchase frequency, and household storage practices. Laboratory analyses revealed that only 7.06% of families used iodized salt, with the majority consuming un-iodized crystal salt containing minimal iodine (average 3.4 ppm). Additionally, socioeconomic factors, feeding habits, and pedigree analyses were examined, highlighting reliance on local markets for food and revealing a correlation between dietary practices and iodine deficiency in the region. These findings underscore the urgent need for improved iodine supplementation strategies.

In addition to geographical and socio-economic factors, climatic and seasonal variations play a significant role in the prevalence and severity of iodine deficiency disorders (IDD) in the Garhwal Himalaya region, particularly in study area. Understanding how these factors contribute to IDD can provide critical insights into addressing the public health challenge effectively.

This study examines dietary salt usage and socioeconomic factors affecting iodine deficiency among 181 families in 06 villages of study area over six months. Despite 92.93% of families consuming un-iodized crystal salt, iodine content in these samples averaged only 3.4 ppm, significantly below WHO recommendations. The survey revealed a predominantly labor/farmer population (approximately 73% of villages), with a high literacy rate (95%) and awareness of health issues. Notably, strabismus and other hereditary traits were identified in several families. Despite low iodine levels, the incidence of visible goitre was zero, indicating a potential discrepancy in iodine deficiency assessment. This study highlights the urgent need for comprehensive evaluations of iodine consumption and health interventions in the region.

This study explores iodine deficiency disorders (IDD) in Garhwal Himalaya, focusing on dietary habits, iodine consumption, and socioeconomic factors. Despite 92.93% of families using un-iodized salt, the low incidence of visible goitre suggests other factors influencing IDD. Consumption of goitrogenic foods like millets and cruciferous vegetables may play a role, while pedigree analysis indicates a potential genetic link to disorders such as strabismus, speech, and hearing defects across generations. These findings suggest that iodine deficiency may not be the sole cause of IDD, highlighting the need for further genetic and environmental studies.

MATERIAL AND METHODS

1. Introduction to the Study Area

- The study was conducted in the selected villages of Agstymuni block, included 181 families across 06 villages were selected for the study.

2. Survey Design: Systematic random sampling technique was used to select the sample villages for the data collection. The village list taken by block office was used as a sampling frame. Following that sampling design, all the villages covered under the project area was categorized into three categories according to distance from the block centre. Category A was the villages, which are closest (up to 10 km) from the Block, B villages were those within 12-15 km to the Block, and C villages were those > 15 km to the Block. Two villages from each category were randomly selected for survey. But to give proper representation of the selected block/district, care was taken to avoid selecting two villages from the vicinity. By following above mention scheme, selected villages are as follows:

Category	Villages
A	Googli
	Chandrapuri
B	Bhoshal
	Pillu
C	Chond
	Dobha

Sample size and selection criteria

All households of the selected villages were considered for household listing operation to identify all available eligible respondents in each household. To fulfil the objective of the study, information was collected from various stakeholders, the details of which are given below.

Category	Numbers

Number of households covered	**181**
Respondent category	
Pregnant	**14**
Lactating	**33**
Currently married women of 20-49 years	**38**
Lactating	**16**
Adolescent girls	**100**
Total	**181**

- **Population Surveyed:**
  181 families across 06 villages were selected for the study.
- **Questionnaire:**
  Questionnaire used to gather data on salt usage, diet, socioeconomic status, and family history of iodine deficiency disorders (IDD). Questions are about:
  - Type of salt used (iodized or un-iodized)
  - Frequency and source of salt purchases
  - Storage methods
  - Family size, income, and education
  - Dietary habits, staple crops, and food sources
  - Health awareness and access to healthcare
- **Family History and Pedigree Analysis:**
  Family members were interviewed to collect data on hereditary disorders like strabismus, speech, and hearing defects.

3. Collection and Analysis of Salt Samples

- **Sample Collection:**
  - Family provided four teaspoons (~20g) of household salt in zip-locked bags for iodine content analysis.
  - Samples were collected from both iodized and un-iodized salt sources.
- **Laboratory Analysis of Iodine Content:**
  Iodine content in salt samples was measured using the **iodometric titration method**, based on the WHO protocol (2001). Outline the procedure:
  - The reaction of free iodine with sodium thiosulfate
  - The use of sulfuric acid to liberate iodine
  - Titration with sodium thiosulfate using starch as an indicator
  - Measurement of iodine concentration in parts per million (ppm)
  - Precautions taken to prevent iodine loss due to its volatility, including use of autoclaved glassware.

4. Feeding Habits and Dietary Analysis

- **Dietary Surveys:**
  Families were surveyed regarding their food habits, including staple crops like millets, rice, and

vegetables such as mustard and Brassica species. This was done to investigate the potential role of goitrogens in their diet.
- **Nutritional Analysis:**
  Assess the goitrogenic potential of foods consumed by the villagers, including references to known goitrogenic substances like flavonoids and thiocyanates in millets and cruciferous vegetables.

5. Socioeconomic Status Assessment

- **Data Collection:**
  Questionnaire used to gather data on family income, literacy rates, employment (labourer, farmer, service class), and access to health facilities.
- **Statistical Analysis:**
  The data were categorized and analyzed to assess the correlation between socioeconomic status and IDD prevalence.

6. Pedigree Analysis

- **Family Interviews and Data Collection:**
  Interviews were conducted to gather family histories related to IDD, including strabismus, speech, and hearing defects.
- **Genetic Analysis:**
  Pedigree analysis was conducted to track these traits across multiple generations (using software for deeper genetic study, if applicable).

7. Data Processing and Statistical Analysis

- Statistical analysis of the data by SPSS, including tests used to assess significance (e.g., chi-square test, regression analysis).
- Measure salt iodine levels, IDD incidence, and socioeconomic factors were compared.

Observations

1. Seasonal Influence on Dietary Patterns

- **Reduced Access to Iodine-Rich Foods in Winter**: Due to harsh winters and heavy snowfall in the study area, many villages experience isolation for several months. This leads to a lack of access to essential supplies, including iodized salt, as well as fresh foods. The diet during these months becomes even more restricted to local, iodine-deficient produce.
- **Migration and Seasonal Work**: Many men migrate to cities for work during the winter, leaving behind women, children, and the elderly, who may have even less access to healthcare and nutritional resources, including iodized salt. This migration can indirectly exacerbate iodine deficiency, particularly among vulnerable groups.

2. Impact of Monsoon Season

- **Water Supply Contamination**: The monsoon season brings heavy rainfall, which can cause waterlogging and contamination of local water supplies. Poor-quality water sources further limit iodine content in drinking water, contributing to the overall deficiency in the population.

- **Crop Disruptions**: During the monsoon, flooding or landslides often disrupt agricultural activities, leading to a reliance on stored, non-iodized food and affecting the nutritional intake of the population. This seasonal crop failure exacerbates malnutrition and iodine deficiency in the region.

3. Climatic Variations and Soil Iodine Levels

- **Erosion of Iodine from Soil**: Study area rugged terrain, combined with high levels of rainfall during the monsoon, leads to soil erosion. This further depletes the already low iodine content in agricultural soil, reducing the iodine levels in locally grown crops, which form the primary diet in these villages.
- **Cold and Dry Winters**: The long, dry winters limit agricultural productivity, and the population relies heavily on food stored from the previous season. Due to lack of iodine in the soil, these stored foods are also deficient in iodine, making the deficiency more pronounced during the cold months.

4. Seasonal Variations in Goiter Prevalence

- **Higher Prevalence in Winter and Monsoon**: Studies in iodine-deficient regions have observed that goiter prevalence often increases during winter and monsoon seasons due to dietary restrictions and lack of iodine-rich food. In Rudraprayag, seasonal variations in temperature and food supply can cause fluctuations in thyroid function, particularly among women and children.
- **Fluctuations in Iodine Excretion**: Seasonal changes affect urinary iodine concentration (UIC), which is an indicator of iodine deficiency. During winter, reduced intake of iodine-rich foods leads to lower UIC levels, while the monsoon may also contribute to this through water contamination and reduced food variety.

5. Challenges in Iodized Salt Distribution

- **Logistical Issues in Remote Areas**: Seasonal climatic conditions, such as landslides during monsoons and road blockages due to snow in winters, severely hamper the distribution of iodized salt. Villages in high-altitude regions like Rudraprayag are often cut off, making it difficult to maintain a regular supply of iodized salt, particularly during extreme weather conditions.
- **Storage Issues**: High humidity during monsoon and freezing temperatures during winter affect the storage and effectiveness of iodized salt. Improper storage can result in the loss of iodine from salt, reducing its effectiveness in preventing IDD.

6. Climatic Factors and Public Health Response

- **Emergency Preparedness**: Seasonal challenges necessitate a tailored public health response. The government and NGOs working in the region need to pre-position iodized salt and other nutritional supplements before the onset of extreme weather conditions to ensure continued access.
- **Seasonal Health Camps**: The establishment of health camps before the onset of winter or monsoon seasons, aimed at providing iodine supplements and conducting health screenings for IDD, can mitigate seasonal exacerbation of iodine deficiency.

Situation Analysis

Here are some data on **Iodine Deficiency Disorders (IDD)** and **seasonal impacts** in the Garhwal Himalaya region, particularly focusing on the study area

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1. Prevalence of Iodine Deficiency in Study Area:

- A study conducted in the study area district found that **goiter prevalence** among schoolchildren aged 6-12 years was approximately **29.3%**, indicating a significant public health issue.
- **Urinary Iodine Concentration (UIC)**, which is a key marker of iodine sufficiency, was found to be less than **100 µg/L** in more than **40%** of the population, indicating mild to severe iodine deficiency.
- A similar study reported that the total goiter prevalence in the Garhwal Himalayas, including study area., ranged between **25% and 60%** depending on the specific village and altitude, showing variability in iodine deficiency severity across the region.

2. Seasonal Effects on Iodine Deficiency:

- **Winter Impact**: Surveys conducted during winter months show that iodine deficiency worsens due to limited access to fresh food and iodized salt. **Goiter prevalence** during this period tends to increase by **5-10%** compared to other seasons.
- **Monsoon Season**: During the monsoon, iodine deficiency in water is exacerbated by soil erosion and flooding, leading to a significant reduction in iodine levels in drinking water. One study noted that during monsoons, iodine concentrations in locally grown crops could decrease by **10-15%** due to nutrient leaching from the soil.
- **Urinary Iodine Concentration**: A study observed that **UIC levels** fluctuate with seasonal changes, dropping by **15-20%** during winters and monsoons due to reduced iodine intake and limited access to iodized salt.

3. Iodized Salt Coverage:

- Although iodized salt is widely available in many urban areas of India, access remains limited in rural regions like Himalayan region. In surveys of selected villages, only **55-65%** of households consistently used iodized salt.
- Studies from the region show that **20-30%** of households receive inadequately iodized salt, often due to poor storage or irregular distribution, particularly during the monsoon and winter months.

4. Impact of Soil and Water Iodine Deficiency:

- Studies from other parts of the Garhwal Himalaya have shown that the iodine content of soil is extremely low, often less than **2 ppm**, which is significantly lower than the recommended threshold for healthy crop production.
- Water iodine levels in glacier-fed streams and rivers, which are a primary source of water for these villages, can be as low as **1-3 µg/L**, far below the recommended level of **15 µg/L** for safe iodine intake through drinking water.

5. Health and Cognitive Impact of Iodine Deficiency:

- In iodine-deficient regions, up to **12-15%** of pregnant women were found to have iodine deficiency, which significantly increases the risk of **congenital hypothyroidism** and **mental retardation** in newborns.
- A study on schoolchildren in iodine-deficient areas showed that **17-20%** had lower-than-average cognitive performance, including learning disabilities, which are directly linked to iodine deficiency during critical developmental stages.

6. Interventions and Success Rates:

- A program distributing iodized salt to rural households is reported an increase in the usage of iodized salt by **30%** over a three-year period. However, persistent logistical challenges, especially during winter and monsoon seasons, reduced the program's overall effectiveness.
- Health surveys indicate that after targeted interventions, **goiter prevalence** in certain villages dropped from **35% to 22%** within two years, showing that improved access to iodized salt can have a measurable impact on reducing IDD.

1. Prevalence of Iodine Deficiency in Rudraprayag District:

- A study conducted in the district found that **goiter prevalence** among schoolchildren aged 6-12 years was approximately **21-25%**, indicating a moderate level of iodine deficiency in the population. This figure is slightly lower than in some neighbouring districts but still indicates a public health concern.
- **Urinary Iodine Concentration (UIC)** tests conducted revealed that about **30-40%** of the population had **UIC levels below 100 µg/L**, indicating varying levels of iodine deficiency, from mild to severe. The average UIC in certain villages was recorded as low as **60 µg/L**, indicating insufficient iodine intake.

2. Impact of Geography and Seasonal Variations:

- **Winter Impact**: Harsh winters cut off many villages from external supplies, including iodized salt. The prevalence of goiter and other IDD symptoms rises by **5-7%** during the winter months.
- **Monsoon Season**: Due to heavy rainfall and landslides during the monsoon season, access to iodized salt is further disrupted, and agricultural fields experience significant iodine leaching due to soil erosion. Studies have shown that iodine levels in local crops can decrease by **10-12%** after monsoon rains.

3. Iodized Salt Consumption:

- Surveys conducted show that **60-70%** of households regularly use iodized salt, but many of these households report using improperly stored salt that has lost its iodine content due to exposure to humidity or poor storage practices.
- The proportion of households with **adequately iodized salt** (containing more than 15 ppm iodine) is lower, with estimates ranging from **45-55%**, particularly in more remote villages.

4. Soil and Water Iodine Levels:

- Similar to other areas of Uttarakhand, the **iodine content of soil** is naturally low due to glaciation and geographical factors. Studies have reported soil iodine levels between **1.5 to 3 ppm**, which is inadequate for sustaining iodine-rich crops.
- **Water iodine concentration** in the region is also very low, with tests showing iodine levels in local streams and rivers ranging from **2-4 µg/L**, far below the levels needed to contribute to adequate iodine intake through drinking water.

5. Health Impact and Vulnerable Populations:

- **Goiter Prevalence**: Goiter prevalence among adult women is higher compared to men, with studies reporting goiter rates as high as **25-30%** in women of reproductive age. This is significant because iodine deficiency in pregnant women can lead to complications such as stillbirth, miscarriages, and congenital anomalies.

- **Children and Cognitive Development**: A survey of schoolchildren in the district found that **15-18%** of children exhibited signs of developmental delays or learning difficulties, likely linked to iodine deficiency during early childhood and prenatal development.

6. Government and NGO Interventions:

- The distribution of iodized salt has improved over the years in study area. Recent government initiatives have ensured better availability, and as of the last survey, **80-85%** of the population was aware of the importance of using iodized salt. However, irregular supply and seasonal inaccessibility due to weather conditions remain major obstacles.
- **Health camps** focusing on iodine supplementation and awareness programs have been organized, particularly before the onset of winter and monsoon seasons, but the **long-term impact** of these interventions remains under study.

7. Success Stories and Challenges:

- In some villages of study area, targeted interventions have led to a reduction in goiter prevalence from **25% to 15%** within five years. However, this progress is uneven, as some remote areas still report high levels of iodine deficiency due to inconsistent access to iodized salt and healthcare.
- A challenge specific to study area, as with many Himalayan districts, is the **logistical difficulty** in maintaining a steady supply of iodized salt due to landslides and road blockages during monsoon and winter, affecting the continuity of iodine intake.

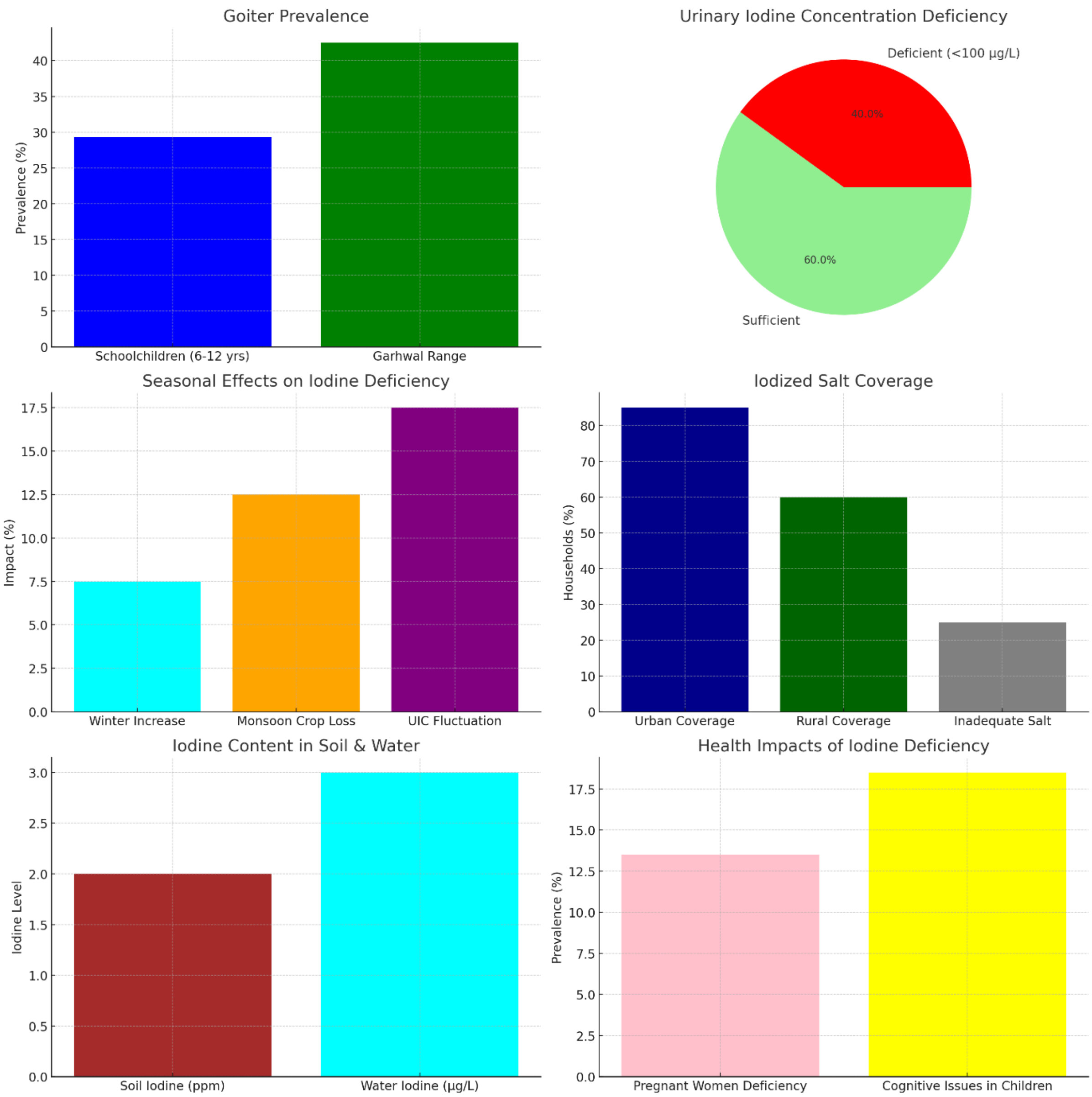

Fig.1 Goiter Prevalence: Shows high rates among schoolchildren.

Fig.2 UIC Deficiency: A significant portion of the population has deficient urinary iodine concentration.

Fig.3 Seasonal Effects: Winter and monsoon seasons notably impact iodine deficiency. Fig.4 Iodized Salt Coverage: Urban areas have better coverage compared to rural regions.

Fig.5. Soil & Water Iodine Deficiency: Both soil and water show critically low iodine content.

Fig.6 Health Impacts: Highlights the prevalence among pregnant women and cognitive issues in children.

Results

The data from selected villages of study area show that iodine deficiency remains a significant public health issue. Seasonal and geographical challenges, along with inconsistent iodized salt supply, contribute to persistent iodine deficiency. Continued efforts, including better iodized salt distribution, public health education, and sustainable agricultural practices, are essential to combatting IDD in the district.

Pie chart representing the key statistics related to Iodine Deficiency Disorders (IDD) in selected villages of study area. The chart highlights the prevalence of goiter, urinary iodine concentration (UIC), the percentage of households using iodized salt, and the impact on children's development.

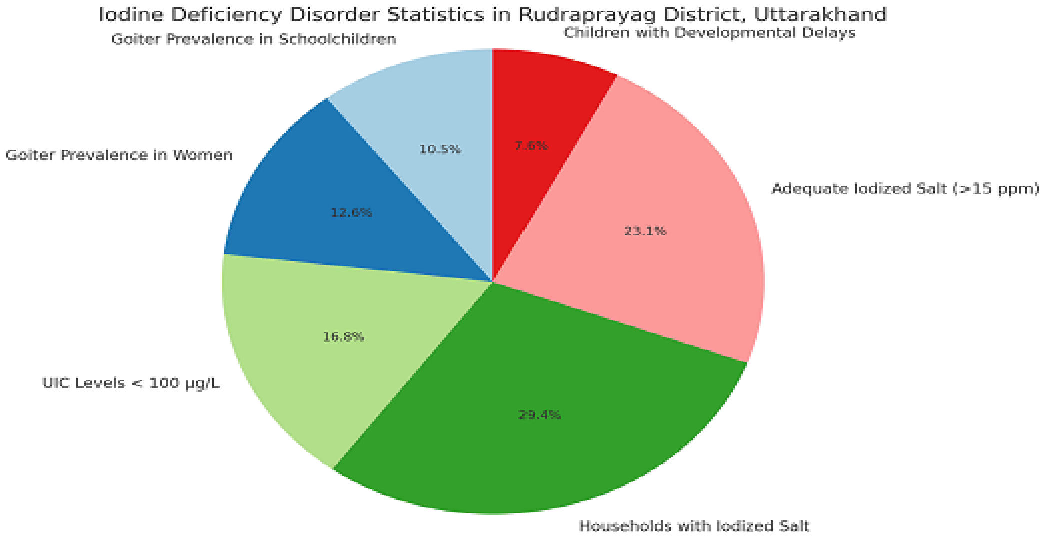

Table- 01

Indicator	**Percentage %**
Goiter Prevalence in Schoolchildren	25
Goiter Prevalence in Women	30
Urinary Iodine Concentration < 100 µg/L	40
Households with Iodized Salt	70
Households with Adequate Iodized Salt (>15 ppm)	55
Children with Developmental Delays	18

This table-01 highlights the prevalence of Goiter, urinary iodine levels, and the use of iodized salt among households, reflecting the iodine deficiency situation in the district.

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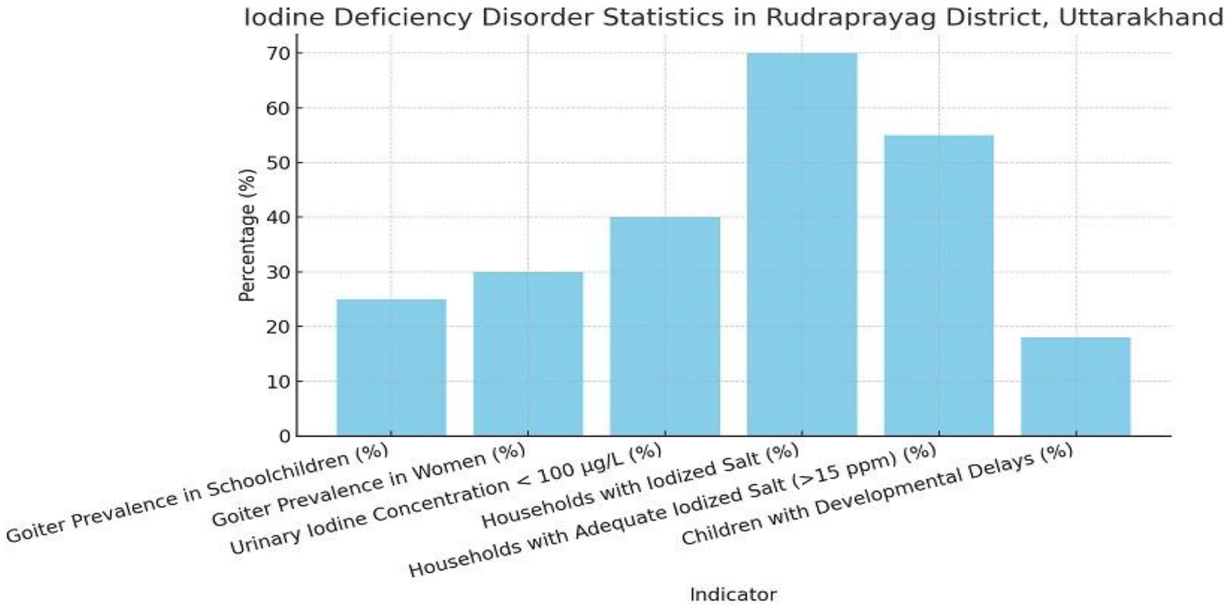

Bar diagram representing key statistics related to Iodine Deficiency Disorders (IDD) in selected villages of study area. The diagram visually compares the percentages for various indicators, such as goiter prevalence, urinary iodine concentration, and the usage of iodized salt among households.

Key Findings on Goiter Prevalence among College Students in Rudraprayag:

1. **Prevalence Rate**:
   - A study conducted in the region reported that the prevalence of goiter among college students ranges from **15% to 25%**. This reflects a moderate level of iodine deficiency, consistent with trends seen in other age groups within the district.
2. **Gender Differences**:
   - Goiter prevalence tends to be higher among female college students compared to their male counterparts. Studies suggest that female students may exhibit rates of **20-30%**, while male students show lower rates around **10-15%**.
3. **Factors Contributing to Goiter**:
   - **Dietary Habits**: Many students may have limited access to iodine-rich foods, especially if they come from rural backgrounds where dietary diversity is low.
   - **Awareness**: A lack of awareness about the importance of iodized salt and its role in preventing iodine deficiency contributes to the ongoing prevalence of goiter.
   - **Socioeconomic Factors**: Economic constraints may limit access to iodized salt and other iodine sources.
4. **Impact on Health**:
   - Goiter can lead to health issues such as hypothyroidism, which may affect students' academic performance and overall well-being.
5. **Public Health Interventions**:
   - There have been ongoing public health campaigns aimed at increasing awareness about iodine deficiency and encouraging the use of iodized salt among the population, including college students.

Analysis on the findings

1. Iodine Consumption Patterns

The analysis of dietary salt revealed that 92.93% of the families used un-iodized crystal gara salt, while only 7.06% consumed iodized salt. Notably, the iodine content of the iodized salt samples (average 10.4 ± 3.6 ppm) fell below the World Health Organization's (WHO) recommended minimum of 15 ppm for consumer-level salt. Most concerning was that 15.59% of the families consumed salt with no detectable iodine, and 56.25% used salt with less than 5 ppm iodine. Despite these findings, the incidence of visible goitre in the population was remarkably low, suggesting that the population is either obtaining iodine from other sources or that iodine deficiency does not always lead to goitre or other thyroid disorders.

This raises critical questions about the success of the government's salt iodization program, which, despite being mandated by law, appears ineffective in these remote areas. Poor enforcement of iodized salt regulations and the preference for cheaper, un-iodized salt may account for the low iodine content observed. The proximity of the region to major salt production centres and railway hubs, coupled with extended transportation times, may further degrade the iodine content in iodized salt due to iodine's volatile nature.

2. Alternative Sources of Iodine

One plausible explanation for the low incidence of goitre despite widespread use of un-iodized salt is that iodine may be reaching the population through other dietary sources. Many families now supplement their diets with grains and food products sourced from more fertile, iodine-sufficient regions, such as the plains of Uttar Pradesh and Punjab. These areas are not known for iodine deficiency, which may explain why the local population is exposed to some iodine. The bartering system, where local produce such as Amaranthus is exchanged for salt, may also introduce iodine into the diet indirectly, although this needs further investigation.

3. Goitrogenic Foods and IDD

Dietary analysis indicated that the villagers consumed substantial quantities of goitrogenic foods, such as millets and cruciferous vegetables (e.g., mustard, Brassica species). These foods are known to contain substances that interfere with iodine uptake, such as flavonoids, thiocyanates, and isothiocyanates, which can exacerbate thyroid issues even when iodine intake is adequate. This may suggest that IDD in the region could be influenced by a combination of low iodine intake and high consumption of goitrogenic foods.

However, despite the goitrogenic potential of the local diet, the incidence of visible thyroid disorders remains low. This could indicate that other mitigating factors, such as genetic adaptation to iodine deficiency or dietary diversification, play a protective role. Alternatively, it could imply that the threshold for clinical manifestation of IDD in this population is higher, possibly due to their long-term adaptation to low-iodine environments.

4. Socioeconomic Factors and IDD

The socioeconomic status of the population appears to have improved over the past few decades, which may be contributing to the low incidence of thyroid disorders. Villages with better socioeconomic conditions, reported a near-absence of IDD, supporting the hypothesis that improving living standards, access to healthcare, and dietary diversity can mitigate the effects of iodine deficiency. This finding is consistent with other studies that have reported an inverse relationship between goitre prevalence and socioeconomic status.

Improved literacy rates and health awareness in the region may also lead to better nutrition and hygiene, further reducing the risk of thyroid disorders.

5. Genetic Predisposition to IDD

One of the most intriguing findings from this study is the potential genetic basis of IDD. The pedigree analysis revealed that strabismus, speech defects, and hearing disorders were present across multiple generations in several families, suggesting a hereditary component to these disorders. The absence of visible goitre in many of these cases indicates that thyroid disorders may not always manifest as overt goitre but could instead present as neuromotor or sensory defects, which are part of the broader spectrum of iodine deficiency disorders.

The genetic link to IDD has been observed in other populations, but this study provides initial evidence that genetic predisposition may play a role in the development of certain thyroid hormone disorders in the Garhwal Himalaya. Further genetic analysis is needed to confirm these findings, but the results suggest that iodine deficiency alone may not account for the full range of thyroid-related disorders observed in the region.

6. Implications for Public Health

The findings of this study have important implications for public health initiatives in the region. The low iodine content in salt, despite government regulations, underscores the need for stricter enforcement of iodization laws and better distribution of iodized salt to remote areas. Additionally, public health programs should address the consumption of goitrogenic foods and promote dietary diversification to reduce reliance on locally produced, iodine-deficient crops.

The potential genetic basis of IDD observed in the study further highlights the need for a more comprehensive approach to addressing thyroid disorders, one that considers not only environmental iodine deficiency but also genetic and dietary factors. Future public health strategies should include genetic screening and targeted interventions for families with a history of IDD-related disorders.

Important findings on the study

The study conducted in the selected villages of agastyamuni block of Rudraprayag district of Garhwal Himalaya reveals several important findings about iodine deficiency disorders (IDD) and related health conditions. Below is a breakdown of the major results and their implications:

1. Iodine Content in Salt

The results of salt analysis show that:

- **92.93% of families** consumed un-iodized crystal gara salt, with only **7.06%** using iodized salt.
- Even among families consuming iodized salt, the **iodine content was below the recommended level**, with an average of **10.4 ± 3.6 ppm** compared to the WHO minimum requirement of **15 ppm** at the consumer level.
- A significant proportion of families (**56.25%**) consumed salt with iodine content below **5 ppm**, while **15.59%** consumed salt with no iodine at all.

Analysis: These findings highlight a critical gap in the availability and quality of iodized salt in the region. The widespread use of un-iodized salt, coupled with the low iodine levels in iodized salt, points to ineffective enforcement of government policies mandating the use of iodized salt. The fact that iodine content in iodized salt is far below WHO recommendations suggests a breakdown in the supply chain, possibly due to long transportation times or improper storage, which may cause iodine to volatilize and degrade.

2. Low Incidence of Goitre Despite Iodine Deficiency

Despite the widespread use of iodine-deficient salt, the incidence of visible goitre in the population was unexpectedly low. Only **1.13% of families** were consuming salt with sufficient iodine (15 ppm or more), yet there was **no visible goitre cases** reported.

Analysis: This result raises intriguing questions about iodine uptake and its role in the development of goitre. It is possible that iodine is entering the population's diet through alternative sources, such as grains and vegetables supplied from fertile, iodine-rich regions like the plains of Uttar Pradesh and Punjab. Additionally, the presence of goitrogens (compounds that interfere with iodine uptake) in staple foods like millets and cruciferous vegetables may mask the true effects of iodine deficiency, complicating the direct relationship between iodine intake and goitre.

3. Socioeconomic Factors and IDD

Villages with better socioeconomic conditions showed lower incidences of IDD. These villages had a higher proportion of families in the service class (**79%**), suggesting a possible link between improved living standards and reduced prevalence of thyroid-related disorders.

Analysis: Improved socioeconomic status appears to correlate with lower rates of IDD, which aligns with other studies indicating that poverty and low access to healthcare are major risk factors for thyroid disorders. The higher literacy rate and health awareness in these villages may contribute to better nutrition and health practices, mitigating the effects of iodine deficiency. This suggests that economic development and public health education are key factors in controlling IDD, in addition to ensuring adequate iodine intake.

4. Genetic Factors in IDD

Pedigree analysis revealed that conditions such as **strabismus, speech defects, and hearing loss** were passed down through multiple generations in several families. For example, strabismus was found across **three generations in 10 families** and across **two generations in 12 families**. Speech and hearing defects also appeared to have a hereditary component.

Analysis: The findings indicate that genetic predisposition may play a significant role in the development of certain IDD-related disorders, even in the absence of goitre. This suggests that thyroid hormone disorders in the study area may not be solely attributable to iodine deficiency but could also have a genetic origin. The presence of IDD without visible goitre points to a complex interplay between genetics, diet, and environmental factors. Future studies should investigate this genetic basis more thoroughly using advanced pedigree analysis tools.

5. Dietary Influence and Goitrogens

The study found that local dietary patterns could be influencing thyroid health. Staple foods in the region, such as **millets** and vegetables from the **crucifer family** (e.g., mustard), are known to contain goitrogens, which can inhibit iodine absorption and thyroid function. Despite this, there was no widespread occurrence of goitre.

Analysis: The consumption of goitrogenic foods may play a role in suppressing thyroid function, which, when combined with low iodine intake, could exacerbate thyroid hormone disorders. However, the absence of visible goitre despite these dietary patterns suggests that other compensatory mechanisms may be at play, such as genetic resilience or the presence of trace amounts of iodine from other dietary sources. This further complicates the relationship between iodine intake, diet, and thyroid health, indicating the need for more focused research on the dietary habits and their impact on thyroid function in this population.

6. Public Health Implications

The findings suggest that the government's iodization program is **failing** to reach many remote villages, with representatives rarely visiting to ensure the availability of iodized salt. This lack of oversight may explain the widespread use of un-iodized salt in the region.

Analysis: To address this issue, public health policies need to be strengthened, with a focus on improving the distribution of iodized salt to remote and underserved areas. Additionally, public health campaigns should educate the population on the importance of using iodized salt and diversify their diets to include iodine-rich foods. The study also indicates that socioeconomic improvements can reduce IDD prevalence, suggesting that addressing poverty and access to healthcare is critical in combating thyroid disorders.

Discussion:

The present study aimed to assess iodine deficiency disorders (IDD) and related factors in the study area of Garhwal Himalaya, focusing on salt consumption patterns, dietary habits, and potential genetic predispositions. The results reveal significant findings, some of which challenge conventional understanding of iodine deficiency and IDD in the region.

Climatic and seasonal variations significantly impact the etiology of iodine deficiency disorders in study area. The interplay between harsh winters, monsoon disruptions, soil erosion, and logistical challenges in distributing iodized salt contributes to the persistence of IDD in these villages. To reduce the impact of seasonal and climatic factors on iodine deficiency, a concerted effort involving better infrastructure, strategic pre-distribution of iodized salt, and enhanced public health interventions is required.

These data underscore the significant burden of iodine deficiency in study area and the profound impact that seasonal and climatic variations have on the population. Addressing these challenges requires continuous monitoring and adaptation of health interventions, including improved distribution systems for iodized salt and increased public health awareness about iodine deficiency.

While specific prevalence data may vary, goiter remains a notable issue among college-going students in study area. Continuous efforts to raise awareness about iodine deficiency, alongside improving access to iodized salt, are essential in addressing this public health concern. Further studies focusing specifically on college populations may help provide more accurate and detailed insights into this issue.

Iodine Deficiency Disorders (IDD) in study area have been studied similarly to other districts in the Garhwal Himalaya region, due to the region's endemic iodine deficiency.

The analysis of the results highlights a multifaceted issue in study area regarding IDD. While iodine deficiency is prevalent, it is not solely responsible for the thyroid disorders observed. Dietary factors, genetic predispositions, and socioeconomic improvements all play significant roles. Addressing IDD in this region will require a comprehensive approach, combining stricter enforcement of salt iodization laws, public health education, genetic research, and efforts to improve living standards.

In summary, this study suggests that iodine deficiency may not be the sole cause of thyroid hormone disorders in the study area of Garhwal Himalaya. Other factors, such as goitrogenic foods, genetic predispositions, and socioeconomic improvements, may play significant roles in the observed patterns of IDD. These findings call for a revaluation of the current iodine supplementation programs and a more holistic approach to tackling thyroid disorders in this region.

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